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RIPPLE-MARKS IN OHIO LIMESTONES[1]

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INTRODUCTION

ORDOVICIAN RIPPLE-MARKS
  Elk Run
  Cherry Fork
  Trebers Run
  Review of Previous Work

SILURIAN RIPPLE-MARKS
  Beasleys Fork
  Lick Fork
  Sproull Glen
  Lawshe Quarry
  Elk Run
  Sharpsville
  Near Peebles
  Near Locust Grove
  Leesburg
  Monroe Formation

DEVONIAN RIPPLE-MARKS
  Sandusky

INTRODUCTION

Dr. Edward M. Kindle, in a "Note on a Ripple-Marked Limestone" in the Devonian of northern Manitoba, published in 1912, stated that: "the occurrence of ripple-marks on sandstone is a common phenomenon to every geologist. . . . . The literature on ripple-marks relates almost entirely to these familiar sand or sandstone ripples. The occurrence of ripple-marks on limestone seems to be a phenomenon of such relative infrequency that it appears desirable to record an example which has come under the writer's notice."[2] In a later paper Dr. Kindle has described ripple-marks in the Trenton limestone near Hull, Quebec,[1] and given a summary of previously described ripple-marks in American limestones.[2] At an earlier date Dr. August Foerste had noted the occurrence of wave-marks (ripple-marks) in the Ordovician and Silurian limestones at a number of localities in Kentucky, Ohio, and Indiana.[3] Recently Professor J. A. Udden has described ripple-marks in the Burlington limestone of Iowa and in limestones of Comanchean age in Texas.[4]

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[1] Published by permission of the State Geologist of Ohio.

[2] *Ottawa Naturalist*, XXVI (December, 1912), 1 (reprint).

On account of the comparative infrequency of described observations of ripple-marks in limestone the writer has concluded to record the most conspicuous of those which he has seen while engaged in field work in Ohio. These will be grouped in the several geologic systems in which they were observed, arranged in ascending order.

ORDOVICIAN RIPPLE-MARKS

Elk Run.—The best ripple-marks seen in the Ordovician are in the upper part of the Richmond formation on Elk Run in the northwestern part of Adams County. This locality is on the Marion Dunlap farm, about 1¼ miles east of Winchester and 3 miles west of Seaman, where the ripple-marked layer of limestone forms the floor of the run for a considerable part of the distance between the Norfolk & Western Railway trestle and the highway bridge. An excellent view of these ripple-marks may be had from the Norfolk & Western passenger trains while crossing the trestle if one looks downstream to the north.

The first series of ripple-marks is on a layer forming the bed of the run a short distance below the trestle and continuing up a branch from the west for about two rods. The direction of the ripple-marks is about due north and south. The more gradual slope (stoss) is to the east, and the steeper (lee) to the west. The distance apart (amplitude) of the crests varies from 28 to 32 inches in the more normal ones, with, in some instances, shorter and more irregular ones between these crests. The depth of the troughs, from the crest to the bottom, varies from 2 to 3 inches. The crests undulate or curve slightly in crossing the surface of the limestone, and this undulation is conspicuous in the bed of Elk Run a little below the branch. Fig. 1 shows the ripple-marks in the bed of Elk Run, just below the railway trestle, and also on the same layer of limestone in the bed of the small western branch.

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[1] *Jour. Geol.*, XXII (1914), 707–9.

[2] *Ibid.*, pp. 709–11.

[3] *Jour. Geol.*, III (1895), 50–60 and 169–97; 1–40 (reprint); *Jour. Cincinnati Soc. Nat. Hist.*, XVIII (1896), 167; *Am. Geologist*, XXXI (1903), 333–61.

[4] *Jour. Geol.*, XXIV (March, 1916), 125, 126; illustrated by Fig. 3, p, 126, Fig. 4, p. 127, and Fig. 5, p. 128.

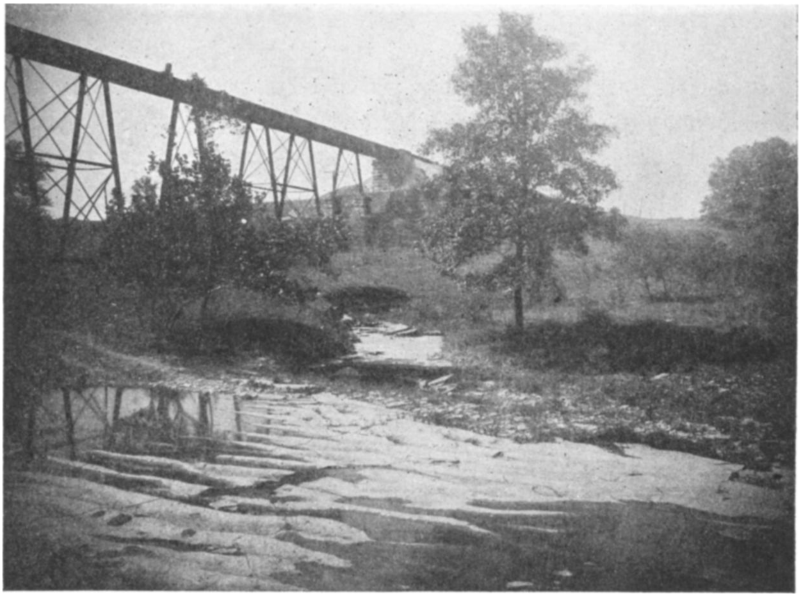

FIG. 1.—View of ripple-marks in bed of Elk Run, just below the Norfolk & Western Railway trestle, $1\frac{1}{4}$ miles east of Winchester, Ohio. Photograph by C. S. Prosser.

There is a dip of at least 1° to the east as measured on the crests of the ripple-marks in the lower part of the branch, and farther up this stream it increases to 2°. The layer of limestone contains large numbers of shells which Dr. Foerste states are covered by sand.[1] It is rather difficult to make out the sand, although there is granular material to some extent. This horizon is given by Dr. Foerste as 60 feet below the top of the Richmond formation.[1]

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[1] *Jour. Geol.*, III (1895), 59.

The dip downstream carries this ripple-marked layer down Elk Run to where it covers the entire bed of the stream for some distance above the highway bridge. At this locality the bed of the stream which is covered by the ripple-marked layer is some 60 feet wide and extends 156 feet along the bed of the stream. This is a beautiful example on a large scale of a ripple-marked limestone. The trend of the crests of some of these ripple-marks is N. 3° W., and they undulate to a considerable extent in crossing the stream. The crests of the normal ripple-marks are from 27 to 32 inches apart. The crests of about three out of five are 29 inches apart, and the average over different parts of the surface of this layer is 29, 30, and 31 inches apart. The more gradual and longer slope (stoss) is to the east, the steeper and shorter slope to the west, and the ripple-marks are clearly asymmetrical. A view of the ripple-marked bed of Elk Run at this locality, looking downstream toward the highway bridge, is shown in Fig. 2. A view of the bed of Elk Run from the highway bridge looking upstream, with the railway trestle in the distance, is shown in Fig. 3.

The layers on the western side of Elk Run below the highway bridge are dipping from 3° to 4°.5 N. 10° E. The majority of readings on the different layers, however, gave 3° for the amount of dip. The barometer gave a dip of 5 feet to the east for the surface of the ripple-marked layer from the branch to the bed of Elk Run under the highway bridge, a horizontal distance of 500 feet.

Just below the highway bridge on the western bank is a ripple-marked layer, between 2 and 3 feet higher than the fine one in the bed of Elk Run which has just been described. The ripple-marks of this higher layer run N. 30° W., are not so conspicuous as in the lower layer, and do not show much difference in the slope of the two sides. On the western side of Elk Run, not far below the highway bridge, is the house of Mr. Charles L. Bailey, and near water-level above the house is a set that runs about northwest and southeast. The eastern slope of these ripple-marks is more gradual than the western slope. Just below the Bailey house a fall is formed by a ripple-marked layer in which the ripples run N. 3–5° W., and the steeper slope is to the west. The crests are from 27 to 28 inches apart, and the ripples are more irregular than those in the bed of Elk Run above the highway bridge. It is not certain that this is the same layer as the one above the highway bridge, and Mr. Bailey, who is interested in geology, states that it is lower. Below the ripple-marked layer in the fall is another one with the ripples running N. 10° W., and the steeper slope to the east, with a more gradual one to the west.

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[1] *Ibid.*, p. 58.

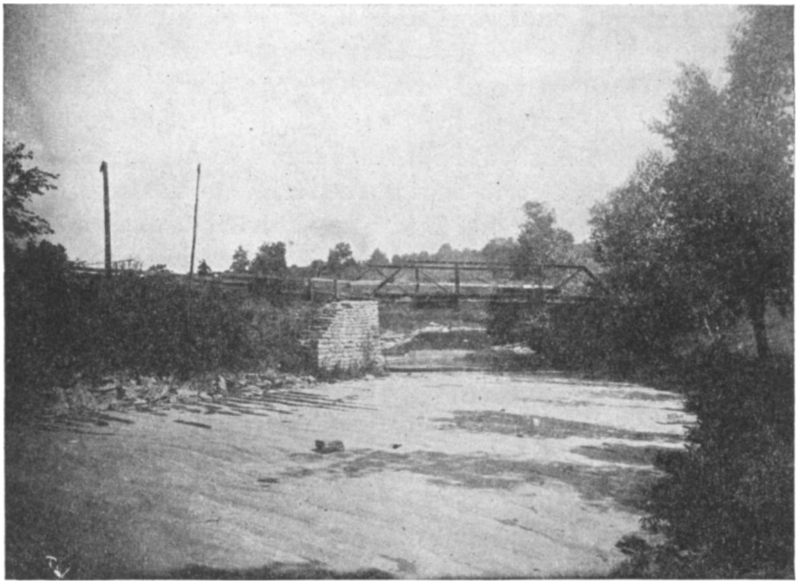

FIG. 2.—View of ripple-marked bed of Elk Run, looking downstream toward the highway bridge. Photograph by C. S. Prosser.

Farther down Elk Run, shown for some rods in the bed of the stream and making a lower fall, is a conspicuous ripple-marked layer, which is 5+ feet below the one forming the Bailey fall. These ripple-marks run N. 10–16° W., the crests are undulating, the slopes steeper to the west than to the east, and the crests from 21, 26, to 27 inches apart. Farther down the run on the eastern side, opposite the E. E. Jamison house, where the pike comes down into the valley of the stream, is a ripple-marked layer. The ripple-marks are not so clearly defined as in the layers farther up the stream; but they apparently run about north and south. Loose blocks of limestone containing pebbles were noted at this locality; but the layer was not located in place. Probably this is the locality described by Dr. Foerste when he says, "Within half a mile of the bridge, farther down, opposite a house on the east bank, plenty of pebbles occur in the rock."[1] Farther down the stream, below the next house on its western side and a ford, is a still lower layer, with not very clear ripple-marks.

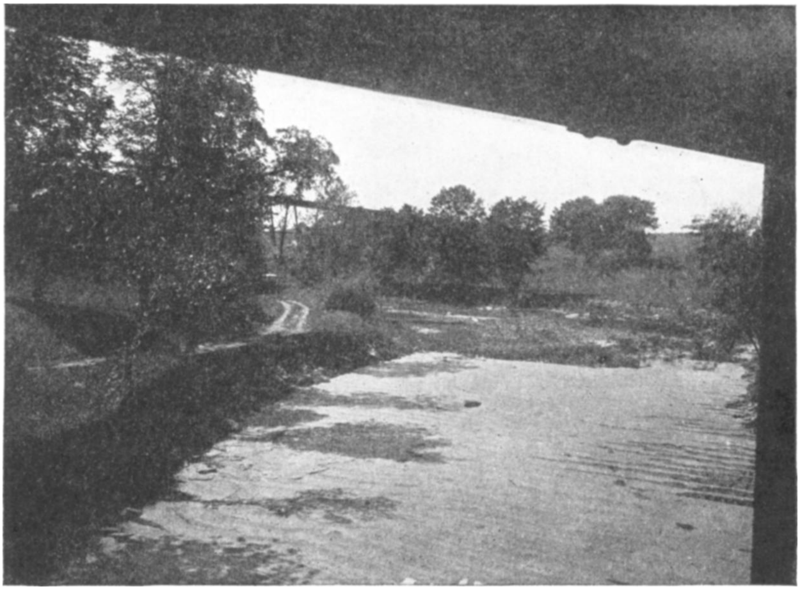

FIG. 3.—View of ripple-marked bed of Elk Run from the highway bridge looking upstream, with the railway trestle in the distance. Photograph by C. S. Prosser.

As noted above, the ripple-marks in the limestones along this stream were first described by Dr. Foerste as wave-marks on Elk Horn Creek.[2]

Cherry Fork.—Ripple-marks in the Upper Richmond were also seen in the bed of Cherry Fork, below the highway bridge at

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[1] *Op. cit.*, p. 59.

[2] *Ibid.*, pp. 58–60.

Harshaville, 4 miles southeast of Seaman, Adams County. The ripple-marks in the highest limestone layer below the bridge run about N. 60° W. and have the more gradual slope to the east of south, and the more abrupt to the west of north. The crests vary from 20 to 28 inches apart. In another limestone layer about 6 inches lower than the first one the ripple-marks run north and south, with the steeper slope to the west and the more gradual one to the east. The crests are from 20 to 30 inches apart. Over part of the floor of the creek below the bridge is a less distinctly ripple-marked layer between the two which have just been described. These run almost directly northwest and southeast, the crests are from 22 to 28 inches apart and are rather flat, and the slope is about the same on each side, making them nearly symmetrical. The northeast slope on a few of them is a little steeper and these do not have such flat crests. Perhaps the tops of the crests of the others have been worn away, which gives them the present somewhat flattened form.

Trebers Run.—This stream is a western tributary of Lick Fork (called Lick Creek on the Highway Map of Adams County), about 5 miles northeast of West Union, 2½ miles below Young's Chapel, about a mile above Dunkinville, and 9 miles southwest of Peebles. On the southern bank of Trebers Run, about 150 yards above the covered bridge on the West Union and Jacksonville Pike, is a ripple-marked limestone layer exposed for 90 feet or more along the bank. This limestone layer is in the upper part of the Richmond formation. At the time this locality was visited the streams were high and the layer was partly covered by water, so that the conditions were not especially favorable for study. Three adjacent ripple-marks run as follows: N. 12° E., N. about 12° E., and the third one about N. and S. The distance between the crests varies from 2 feet 2 inches to 2 feet 7 inches, while the depths of the furrows (troughs) is from 2½ to 3 inches. The eastern slope of the ripple-marks is perhaps a little steeper; but there is comparatively little difference in the slope of the two sides. There is a heavy dip for this region downstream to the east, and certain layers on the northern bank some rods farther up the run dip from 4°.5 to 5° N. 100° E.

This stratum is known locally as the "washboard" layer, and it is apparently the one described by Dr. Locke in 1838. He stated that "the waved stratum at Treber's is exposed in the bed of the fork, about 400 feet in length, and 50 feet in width."[1] Mr. William Treber, now eighty-nine years old (July, 1915), who lives on the Treber farm just south of the run, remembers when Dr. Locke studied this locality, and his daughter, Lizzie Treber, stated that the layer described by Locke is believed to have been exposed in the field a few rods northeast of the lower part of Trebers Run, on the eastern side of the Pike. Lick Fork has shifted its bed somewhat to the east and, the locality is now covered by soil. The strong easterly dip would probably carry the layer now exposed on Trebers Run down to the locality where it is stated that the ripple-marks described by Dr. Locke were exposed. The barometer gave a difference in altitude of 110 feet from Lick Fork at Trebers to the top of the Richmond formation on Lick Fork above Young's Chapel, 2½ miles above Trebers. Miss Treber also stated that formerly the ripple-marked layer was exposed in Lick Fork, about opposite their house, as well as above it; but the high water at the time this locality was studied prevented determining whether any of the layer is now shown when the water in the stream is at its normal height.

Review of previous work.—Ripple-marks in the Upper Richmond in Ohio, so far as known to the writer, were first described by Professor John Locke from outcrops on Lick Fork,[2] about 5 miles northeast of West Union, Adams County. Locke called it the "waved stratum" and located its horizon as 55 feet below the top of the blue limestone, No. V of his section, and he stated that near a house known as Trebers it was exposed "in the bed of the fork, about 400 feet in length, and 50 feet in width."[3] Professor Locke, however, stated that "these waves are not local, but may be traced in the same stratum over tracts of many miles. They have been called 'ripple marks'; but all geologists will agree that the blue limestone has been formed far below the reach of 'ripples.'"[4]

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[1] *Second Ann. Rept. Geol. Survey Ohio,* 1838, p. 247 and bottom of Pl. 6, opposite p. 242.

[2] *Second Ann. Rept. Geol. Survey Ohio,* 1838, pp. 246, 247, and Pl. 6, opposite p. 242.

[3] *Ibid.,* p. 247.

[4] *Ibid.,* p. 246.

Messrs. Joseph Moore and Allen D. Hole have described "ripple-marks in Hudson River limestone, in Wayne County, Indiana, 5 miles southwest of Richmond," which are illustrated by 3 plates.[1] These are probably in the Richmond formation and it is stated that "the mean distance from crest to crest is approximately uniform for the series, and the average for twenty such distances is found to be 2.63 feet. The average depth of lowest part of troughs below crests is $1\frac{1}{2}$ to $1\frac{6}{10}$ inches."[2] At an earlier date W. P. Shannon had described "wave-marks on Cincinnati limestone" in the bed of Salt Creek, 3 miles west of Oldenburg, in the southwestern part of Franklin County, Indiana.[3]

Dr. Orton called attention to the observations of Professor Locke and stated that "it is an even more striking characteristic of the rock in its lower beds [Cincinnati group], as shown in the river quarries of Cincinnati, or in the lowermost 100 feet that are there exposed. . . . . The interval between the ridges varies, but in many instances it is about 4 feet. The greatest thickness of the ridge is 6 or 7 inches, while the stone is reduced to 1 or 2 inches at the bottom of the furrow, and sometimes it entirely disappears."[4] Dr. Foerste also noted wave-marks and ripple-marks in the "Lower Hudson, or Utica" opposite Cincinnati, at West Covington, Kentucky,[5] which in general "run slightly east of north."[6] Recently Dr. Kindle has reported Dr. Foerste as stating that "wave-marks (ripple-marks) occur in Ohio, Indiana, and Kentucky, in abundance in the Lower Eden, Upper Richmond, and Upper Brassfield limestones. They occur in great numbers, but not so abundant, also in the Middle Eden. In Kentucky they are common also locally in the Mount Hope bed, at the base of the Maysville. They occur often near the middle of the Arnheim and at various intervals in the Lower and Middle Richmond in the three states mentioned."[7]

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[1] *Proc. Indiana Acad. Sci.*, 1901 (1902), pp. 216–20.

[2] *Ibid.*, p. 217.

[3] *Ibid.*, 1894 (1895), pp. 53, 54.

[4] *Rept. Geol. Survey Ohio*, I (1873), 377.

[5] *Jour. Geol.*, III (1895), 56–58.

[6] *Ibid.*, p. 58.

[7] *Ibid.*, XXII (1914), 709, 710.

SILURIAN RIPPLE-MARKS

Beasleys Fork.—Ripple-marks in the upper part of the Brassfield limestone (formerly called Clinton) were noted at several localities in Adams County. One of these localities is in the bed of the upper part of Beasleys Fork, some distance above the house of Walter D. Grooms, which is about 1¼ miles south of West Union on the Wrightsville Pike. This stream is crossed by three layers of limestone in which ripple-marks are conspicuously shown.

The lowest layer is a very crinoidal limestone, from 3 to 10 inches thick, which forms a small fall, and its top is about 8 feet 3 inches below the top of the Brassfield limestone. The ripple-marks run about east and west, with the more gradual slope to the north and the steeper toward the south. The top of the second or middle ripple-marked layer is 4 feet 11 inches below the top of the Brassfield formation, and the layer itself is 5± inches thick, but the ripple-marks are not so conspicuous as in the layer below and the one above. These ripple-marks run north and south with the steeper slope on the east side and the more gentle slope on the west. Finally, there is the third or highest ripple-marked layer, the top of which is 4 feet 5 inches below the top of the Brassfield, and opposite the small house on the bank of the creek on the Joe Morrison farm. The layer is a grayish, somewhat greenish-spotted, crystalline limestone, 8± inches thick. The ripple-marks run about north and south, with the steeper slope to the east and the more gradual to the west. These ripple-marks are heavy and the crests are 26, 31, 34, 35, and 38 inches apart. The distance from the bottom of the trough to the top of the ridge varies from 3 to 9 inches.

These ripple-marks were noted by Dr. Foerste in his description of the section "along the road to Beasley Fork." The following is that part of this section in which the ripple-marks occur, as described by Dr. Foerste:[1]

	Ft.	In.
Limestone, wave-marked		3
Clay		8
Limestone		3
Clay		3

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[1] *Kentucky Geol. Survey, Bull. No. 7,* 1907, p. 42.

	Ft.	In.
Limestone, with large wave-marks		6
Limestone		6
Clay, with a little thin limestone	1	6
Limestone with large wave-marks and containing large crinoid beads		6

Lick Fork.—At least two ripple-marked layers in the upper part of the Brassfield limestone occur on Lick Fork (called Lick Creek on the Highway Map of Adams County) above and below the highway bridge on the West Union and Jacksonville Pike, about 2¼ miles northeast of West Union and about opposite the house of J. Frank Young. Stratigraphically, what is apparently the lowest ripple-marked layer outcrops a few rods above the bridge, where there is a strong dip downstream. The rock of this layer is a very crystalline and crinoidal limestone containing large cup corals and numerous fragments of other fossils in its upper surface. The ripple-marks are large and one of them runs N. 70° E., although some of them run perhaps more nearly east and west. The crests of two of them are 30 inches apart, and of another set 31 inches apart. The trough is 3½ inches deep and the slope much steeper on the southern than on the northern side. A few rods below the bridge is a layer with ripple-marks which run N. 20° W. and S. 20° E. The crests of these ripple-marks are about 31 inches apart and the western slope is steeper than the eastern one. This ripple-marked layer is about 19⅔ feet higher than the base of the Brassfield limestone. Not far above the highway bridge are ripple-marks running N. 18° W. and S. 18° E., which apparently occur in the same layer as those below the bridge, which have just been described. Farther upstream the direction of the ripple-marks, apparently on this same layer, has changed to N. 74° W. Not much farther upstream than the ripple-marked layer first described one is shown in the bed of the stream, which may be higher than the others; but its stratigraphic position was not certainly determined. The ripple-marks of this layer run north and south, the crests are 30–35 inches apart, and there does not appear to be a marked difference in the angles of the slopes.

This is probably the locality where Professor John Locke noted two waved layers in the Flinty limestone (Brassfield), No. III of his section, on Lick Fork.[1] He gave the top of the upper one (No. 13) as 4 feet 9½ inches below the top of a flinty layer (No. 1) (apparently one of the layers of the Dayton limestone), which he seemed to consider the top of the flinty limestone.[2] This upper "waved stratum" is given as 3 inches thick, with 20 inches mostly of marl between it and the lower "waved layer" (No. 17) which is reported as 7 inches thick.

Sproull Glen.—This glen is on the R. C. Sproull farm, now owned by Mrs. Jennie Black and Dr. O. T. Sproull, not far from Sproull Bridge over Ohio Brush Creek, 6 miles southwest of Peebles. The heavy rains of July, 1915, had deepened and cleared out the bed of this stream to such an extent that three layers of ripple-marked limestone were exposed which on a visit to the same glen in September, 1914, were not seen.

The lowest ripple-marked layer was shown on the northern side of the stream with ripple-marks running N. 10° W. to N. 30° W. One foot 5 inches higher is another limestone layer 7 inches thick with ripple-marks imperfectly shown on its upper surface. Also 3 feet higher ripple-marks occur on thin layered limestones; but the last two layers were so poorly shown that not many data could be obtained concerning the ripple-marks. The top of the third or highest ripple-marked layer is 9 feet 9 inches below the base of the 10-inch zone of *Whitfieldella quadrangularis* Foerste[3] in the Brassfield limestone, and 9 feet 3 inches below the top of this formation as exposed in the third fall, or 13 feet 6 inches below the top of the very hard Dayton limestone as exposed in the stream above this fall.

Lawshe quarry.—This old quarry is located on the Vincent Robbins farm, north of Lawshe, Adams County, on the Cincinnati Division of the Norfolk & Western Railway. Ripple-marks were noted near the western end of the quarry, which are not well exposed but run N. 16° E. The ripple-marked layer occurs from 1 foot 4 inches to 2 feet below the base of a rather conspicuous 2 foot 2 inch layer, which is 12 feet 10 inches above the top of the "chert zone" in the basal part of the Brassfield limestone and 16 feet 10 inches higher than the lowest outcrop in this quarry. The 2 foot 2 inch layer is variously colored crystalline limestone, which on the weathered faces is apparently cross-bedded and contains a good many pebbles, more or less flat, and some of them of considerable size. The top of the massive layer just described is about 22 feet below the top of the Brassfield limestone and nearly 24½ feet below the top of the hard Dayton limestone.

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[1] *Second Ann. Rept. Geol. Survey Ohio*, 1838, pp. 244, 246, and Pl. 6, opposite p. 242, on which only one waved layer is indicated in the flinty limestone.

[2] *Ibid.*, p. 244, where he states that "the upper layer of the flinty stratum is peculiarly marked. It is about one foot thick, and contains so much silex that it has the sharp conchoidal or flinty fracture, and gives fire with steel."

[3] *Kentucky Geol. Survey, Bull. No. 7*, 1906, p. 41.

Elk Run.—On Elk Run (called Elm Run on the Highway Map of Highland County), 2¼ miles northeast of Belfast, Highland County, are ripple-marked layers in the Brassfield limestone, which are well shown in the stream a few rods below the iron highway bridge on the upper road from Belfast to Elmville. This layer is a crystalline limestone, from ½ to 3 inches thick, which contains fossils and some pebbles. The ripple-marks run N. 80° E., the steeper slope is to the north and the more gradual one to the south. The crests range from 26 to 36 inches apart, 32 inches being the most frequent distance. The deepest trough noted is about 2½ inches lower than the crest. A ferruginous limestone 1 foot 4 inches thick occurs just above the crystalline, ripple-marked layer, and another 4-inch ferruginous limestone layer just above this, the upper surface of which is apparently ripple-marked. Below the ripple-marked, crystalline limestone is a layer 1 foot thick containing fossils and numerous pebbles of Brassfield limestone. The majority of the pebbles are rather flat and fairly well rounded on the margins. The size of some of the larger pebbles is indicated by the following figures: one 8½ inches long, and three rectangular ones respectively 9×6, 9×8, and 9×8½ inches. The pebbles as a rule lie flat (horizontal) or at least nearly so in the rock; but there are some that are imbedded at more or less of an angle.

Attention was first called to this locality by Dr. Foerste, who has written as follows concerning it:

> By far the most interesting feature of the locality, however, was the presence of great wave-marks, wonderfully distinct and well exposed for a distance of a hundred feet down the creek. The line of strike of these wave-marks was magnetically about north 65° east. The crests of the wave-marks

were about two inches above their greatest depressions, and the distance from one crest to the next was on the average about 28 inches. They sloped northwards a little more steeply than southwards. This wave-marked layer is only from one to two inches in thickness, and immediately overlies a great mass of pebbles, imbedded in the Clinton just beneath. These pebbles sometimes project strongly into the sandy layer above, which shows the wave-marks. The pebbles are on the average larger than at any place where pebbles have so far been seen in the Clinton. Plenty of them are 12 inches in diameter, and many of them range between four and eight inches. As usual, the pebbles are only an inch to an inch and a half in thickness. Lithologically they are similar to the sandy stratified layers of the Clinton limestone, found characteristically in the lower half of the Clinton in this part of the state, and occurring also at higher levels. If there had been any doubt hitherto about the Clinton age of these pebbles, it was dispelled by the fossils found in some of the pebbles at this locality.[1]

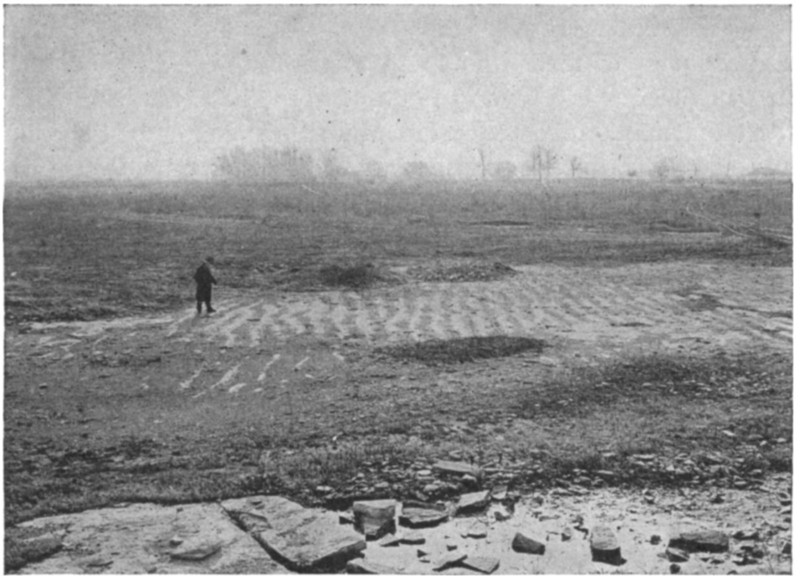

FIG. 4.—View of ripple-marks as formerly shown in the old Schoepfle quarry, Sandusky, looking southeast. Photograph by C. W. Platt.

Sharpsville.—On Turtle Creek, above Sharpsville, in the western part of Highland County, ripple-marks were noted in the Brassfield limestone; but there was not an opportunity to measure them. Opposite Sharpsville and farther down Turtle Creek than the place above mentioned Dr. Foerste reported "a thin, sandy layer, very undulated, like ripple-marks where waves have crossed from various directions. Their importance was not appreciated, when observed, and their direction was not carefully noted. Judging from the memory alone the larger ripples had a general northeast course and indicated currents transverse to this direction."[1]

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[1] *Jour. Geol.* III (1895), 184.

Near Peebles.—In the Peebles Stone Company quarry, on the northern side of the Norfolk & Western Railway, one-half mile west of Peebles, is a layer 7 feet 10 inches above the base of the West Union limestone, the surface of which is conspicuously ripple-marked. The rock is bluish gray in color, massive, contains Brachiopods, and the upper surface is very crinoidal. On the crests of the ripple-marks are furrows which are apparently trails. The majority of the ripple-marks run in a regular direction, which is N. 6° W.; but an occasional one runs in an irregular direction. The distance between two parallel crests is 27 inches and the trough is $1\frac{1}{2}$ inches deep. The distance between two other conspicuous crests is 3 feet 10 inches, with a much smaller ripple-mark about half-way between them. In general the eastern slopes appear to be the steeper, although part of them do not show any particular difference, and one is apparently steeper on the western side.

About one-fourth mile west of Peebles in the bank of a small stream on the northern side of the Norfolk & Western Railway ripple-marks occur in Niagaran limestone. Ripple-marks are clearly shown in two layers of crinoidal limestone at this locality. In the lower layer one of the ripple-marks runs N. 6° W., and another one, N. 2° W. The crests are 22–23 inches apart and one trough is 4 inches deep. In general the more gradual slope is to the east and the steeper to the west, although in one of them the eastern slope appeared to be the steeper. In the upper layer the ripple-marks run N. 5° E., the crests are 44–45 inches apart, a trough is $4\frac{1}{2}$ inches deep, and the steeper slope is to the east.

This locality was described as follows by Dr. Foerste:

> Along the railroad about a quarter of a mile west of Peebles, where the railroad crosses a creek, there are very good wave-marks in the rock on the

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[1] *Jour. Geol.*, III (1895), 178.

north side of the railroad, in a sort of quarry. The rock is of a bluish tint, and is some distance above the Niagara shales. It is presumably of the Springfield horizon. The crests of the waves run here north 3° east; they are about 3½ inches above the troughs of the waves, and are about 42 inches apart, showing therefore approximately the same characteristics as the waves of Clinton age in Elk Run. They descend more rapidly eastward than westward. The wave-marks are seen at several levels through a thickness of 2½ feet of rock. . . . . Where the railroad crosses the creek, 50 feet towards the southeast, the wave-marks are shown over a larger area. The crests here run north 5° west.[1]

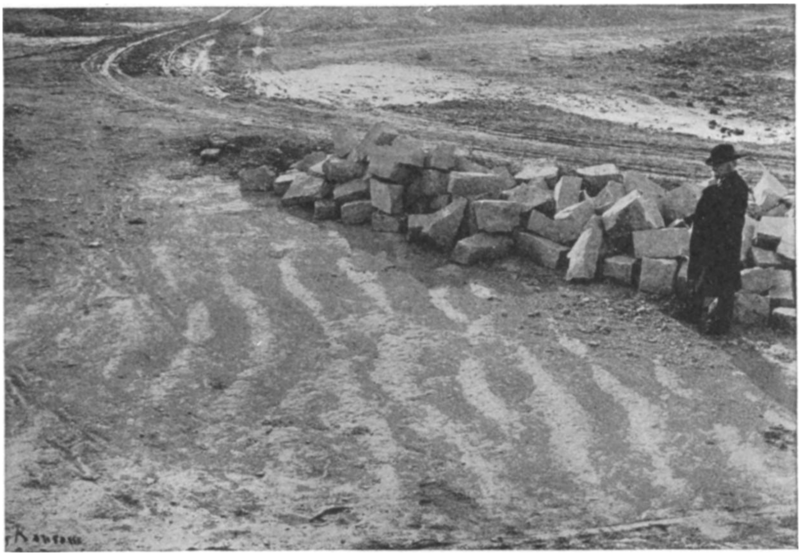

FIG. 5.—Nearer view of part of layer shown in Fig. 4. Photograph by C. W. Platt.

Dr. Kindle has also made reference to this locality.[2]

Another locality of Niagaran ripple-marks is southwest of Peebles on the dirt road for Lawshe, about one-fourth mile west of the West Union and Locust Grove Pike. The ripple-marks are shown in the highway to the west of a run, and the first house to the west is that on the farm of James Graham. The ripple-marks run north and south, the crests are 20, 21, and three of them 24 inches apart. The more gentle slope appears to be to the west

[1] *Jour. Geol.*, III (1895), 190.

[2] *Ibid.*, XXII (1914), 711.

and the steeper to the east. These ripple-marks occur in somewhat thin-bedded dolomites, like those to the west of Peebles, called Springfield by Dr. Foerste, and apparently are in the southern continuation of those beds.

Near Locust Grove.—On the western side of Locust Grove branch of Crooked Creek, 1 mile west of Locust Grove and nearly opposite the house of James Ogden, in the West Union limestone are ripple-marks running N. 12° W. and S. 12° E. Some rods farther downstream and 30 feet higher on the bank in the West Union limestone are rather large ripple-marks running N. 10° W. and S. 10° E.

Leesburg.—Ripple-marks occur in Lee's Creek in the gorge below the Davis Mill and north of Leesburg in the northern part of Highland County. The ripple-marks occur in the Blue Cliff dolomite, which Dr. Orton correlated with the Springfield dolomite, and just below a massive layer 7½ feet thick, which is well shown on the eastern side of the creek where the rock has been quarried to a small extent. The ripple-marks are rather irregular; but one runs N. 30° E. and they appear to be steeper on the western slope than the eastern.

Monroe formation.—Ripple-marks were noted at three horizons in the Monroe formation, 2½ miles east of Peebles; but the area exposed in each case was too small and the ripple-marks too imperfect to make any definite measurements. The lowest layer is exposed in the bed of Morrison Run some distance below the spring and house of John K. Morrison, on the road to Bacon Flat schoolhouse, and it is about 15 feet higher than the base of the formation. The highest one is shown in the highway leading up the hill to the west of the John K. Morrison house, and is stratigraphically some 86 feet higher than the base of the Monroe. The direction of these ripple-marks is somewhat irregular; but they run about east and west. The third and intermediate horizon is on a layer in the Virginia Product quarry, just south of the Norfolk & Western Railway, about 2½ miles east of Peebles, and it is more than 25 feet above the base of the Monroe dolomite.

DEVONIAN RIPPLE-MARKS

Sandusky.—The best example of ripple-marks in the Devonian limestone that the writer has seen is in Plant No. 2 of the Wagner

Stone Company (formerly known as the Schoepfle quarry), on Hancock Street in the southern part of Sandusky. Formerly there was a considerable area of the floor of this quarry on which ripple-marks were beautifully shown, the three views of which reproduced in this article were furnished by Mr. DeLos C. Ransom, of Sandusky, Ohio, who first called the writer's attention to them in January, 1902. Most of this area, however, has been destroyed by the work of the Wagner Stone Company, and when studied on September 19, 1914, only a small portion of it remained, which was located about east of the crusher and on both the east and west sides of the quarry track running from the crusher around to the new part of the quarry to the northwest. This ripple-marked

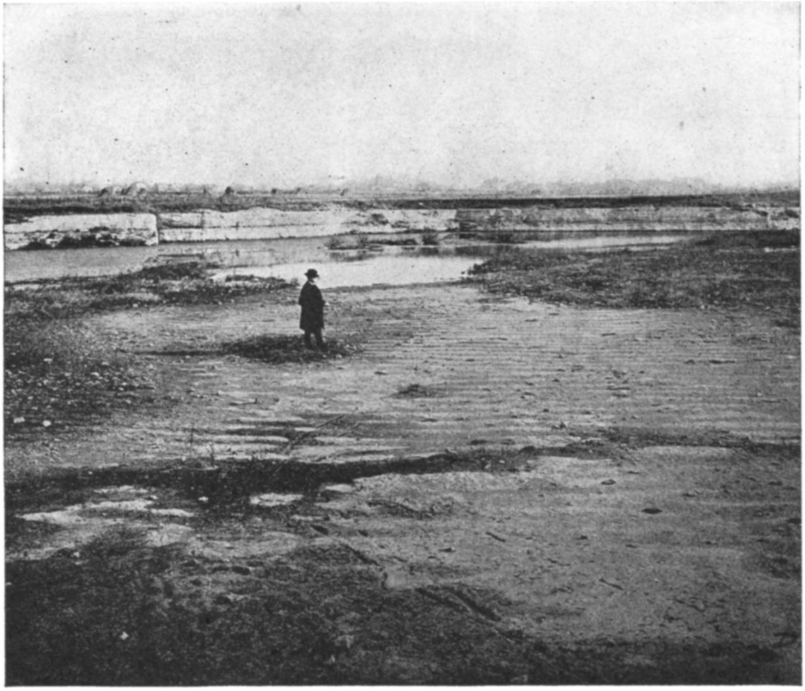

FIG. 6.—View of ripple-marks as formerly shown in the old Schoepfle quarry, Sandusky, looking northeast and at right angles to Fig. 4. Photograph by C. W. Platt.

layer is in the upper part of the Columbus limestone, the western continuation of the Onondaga limestone of New York.

In general, the crests of the ripple-marks which remained in September, 1914, run N. about 20° W., but those farthest to the west run N. about 25° W. Occasionally two will run together and, in one case at least, then diverge again. The crests of those studied vary from 22, 24, 25 to 26 inches apart, the greater number of them being about 2 feet apart. Mr. Ransom reported those shown in the half-tones as "being 3 to 4 feet from crest to crest."[1] In the somewhat worn surface of the layer it is difficult to distinguish any particular difference in the angle of slope of the two sides; although, perhaps, some of the ripple-marks west of the quarry track are a little steeper on the southwest side, with a little longer slope on the northeast side. The troughs of these ripple-marks are rather shallow, although the exact depth was not determined. Figs. 4, 5, and 6 are from photographs, furnished by Mr. DeLos C. Ransom, of the floor of the old (Schoepfle) quarry, showing the ripple-marks as they formerly appeared before this layer was mostly destroyed by the extensive work of the Wagner Stone Company. Mr. Ransom has stated that in Figs. 4 and 5 the camera was pointed toward the southeast and parallel to the direction of the ripple-marks. In Fig. 6 the direction across the ripple-marks is toward the northeast, at right angles to Fig. 4, and the crests are three or four feet apart.[2] Mr. Ransom has written several times concerning these ripple-marks, and the following quotation is from one of his letters:

> Now such ripple-marks 3 or 4 feet wide as are in limestone must have been constructed in water 50 to 100 feet deep and waves of immense size in the ancient comparatively shallow and wide sea when our limestones were laid down. "Ripple-marks" hardly expresses or describes these large parallel stone *waves*. They are perpendicular to the direction of the wind, hence aeons ago winds were as now largely S.W. and N.E. and hence the poles of the earth have not changed since.[3]

[1] Letters of January 25, 1902, and October 28, 1903.

[2] Letter of September 25, 1915.

[3] Letter of October 28, 1903.

On September 19, 1914, a considerable area in the new (northwest) part of the quarry had been stripped of soil and this upper surface of the limestone was beautifully glaciated. It was all worn smooth and marked with striae of various degrees of strength; but part of them are rather strong. The direction of the striae was determined at different places on this surface and in all cases they ran N. 100° W. (W. 10° S.) and N. 80° E. (E. 10° N.).